A review on crop residue burning: Impact and its management

K Jaisimha Reddy and Shivanand Goudra

Abstract

Harvesting of various crops generates a substantial amount of residues on and off the farm. In India, around 500 Mt of crop residues are generated annually. Cereals generate the most agricultural residues (352 Mt), followed by fibres (66 Mt), oilseeds (29 Mt), pulses (13 Mt), and sugarcane (12 Mt). Cereal crops (rice, wheat, millets) produce 70% of crop residues, whereas rice alone contributes 34%. The problem is more severe in the irrigated Indo-Gangetic plains, particularly in the mechanized rice-wheat system of the northwest India (Punjab, Haryana, Uttarakhands plains and Western UP). The major constraints in the rice-wheat cropping system are less time available between rice harvest and sowing of wheat and also shortage of labour. This leads farmers towards mechanical harvesting, resulting in burning of huge amount of crop residues in the field itself. Crop residue burning leads to loss of plant nutrients such as N, P, K and S, impacts soil physicochemical, biological and microbial properties by elevating soil temperature, and also causes emission of greenhouse gases (GHGs) such as CO₂, CH₄ and N₂O causing global warming. Various technological interventions to reduce crop residue burning include incorporation of crop residue into soils through adoption of conservation agriculture practices, promotion of use of crop residue for preparation of bio enriched compost or vermicomposting, use of crop residue for cultivation of mushrooms, diversification of the use of crop residues as fuel for power plants, production of cellulosic ethanol and incentives for the purchase of happy seeder or turbo seeder or shredder or baling machines and extending subsidy to the farmers for hiring resource conservation machineries from custom hiring center or agriculture service center etc.

Keywords: Crop residues, global warming, greenhouse gases, technological interventions

1. Introduction

1.1 Global context

Crop residue burning is a worldwide occurrence, with many nations participating in this so-called menace. China, India, and the United States are the largest consumers of crop residues globally. Other major contributors to crop residue burning include Brazil, Indonesia, and the Russian Federation. Nonetheless, relative to other continents, Africa has some of the highest rates of residue burning per hectare of harvested land. It is also the zone where fires are spreading the quickest. Burning has advanced dramatically in nations such as Brazil, Indonesia, Thailand, India, and China over the past several decades.

1.2 Indian context

According to a study undertaken by the Ministry of New and Renewable Energy (2019), around 500 million tonnes of crop residues are produced annually. As per the same report, the bulk of crop residue is utilized for animal feed, fuel, and other domestic and industrial applications. However, there is still a 140 Mt surplus, of which 92 Mt are burned annually. Uttar Pradesh generates the most crop residues (60 million tonnes), followed by Punjab (51 million tonnes) and Maharashtra (46 million tonnes). Cereals produce the most residues (352 million tonnes), followed by fibres (66 million tonnes), oilseeds (29 million tonnes), pulses (13 million tonnes), and sugarcane (12 million tonnes). Nearly 70% of total agricultural wastes come from cereals (rice, wheat, maize, millets). Rice and wheat account for almost 58% of all crop residues. Rice, wheat, and sugarcane account for an astounding 82% of India’s total crop residue burning. Cotton contributes to 8% of the crop residue burning while jute and maize contribute 3% each.
1.3 Reasons for burning of crop residues in Northern India

With the availability of photo-insensitive, short-duration wheat and rice cultivars, it is now possible to cultivate high-yielding rice crops in 120–130 days. Less time between rice harvest and wheat planting, as well as a labour scarcity, prompted farmers to adopt mechanization. The mechanical harvesting using a combine harvester leaves vast quantities of stubble in the field. Therefore, farmers find that burning rice stubble is the simplest and most cost-effective way to dispose of it.

Due to the loss of ground water caused by paddy cultivation, the governments of Haryana and Punjab enacted legislation whose purpose was to preserve ground water. In 2009, both the Punjab Preservation of Subsoil Water Act and the Haryana Preservation of Subsoil Water Act were enacted. In addition to bringing the crop cycle closer to the monsoon and conserving ground water, as intended, these measures shortened the period between wheat harvests. This reduced the amount of time farmers had to remove crop debris and compelled them to burn it.

Post-harvest burning of the crop residues in Punjab, Haryana, Rajasthan, and western Uttar Pradesh increased the particulate matter significantly in the environment. Unfortunately, this occurred with the October/November onset of winter in northern India. The shift in wind direction and the decrease in temperature make it difficult to disperse the particulate matter produced by agricultural waste burning. It is a major health concern in the northern region of the country, particularly in densely populated and industrialized NCR Delhi. It has become a top priority for the state and federal governments.
It is clear from the figures that higher incidence of fires occurred over the IGP region, mainly in the Punjab and Haryana state followed by Uttar Pradesh, Madhya Pradesh and Maharashtra.

<table>
<thead>
<tr>
<th>End use</th>
<th>Rice (% of total stubble production)</th>
<th>Wheat (% of total stubble production)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burnt</td>
<td>81</td>
<td>48</td>
</tr>
<tr>
<td>Fodder</td>
<td>7</td>
<td>45</td>
</tr>
<tr>
<td>Soil incorporation</td>
<td>1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Rope making</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

Gupta et al. (2019)

**2. Impacts of Crop Residue Burning**

**2.1 Impact of crop residue burning on environment**

The main negative effects of burning crop residues include the emission of greenhouse gases (GHGs) that contribute to global warming, the increase in levels of particulate matter (PM) and smog that pose health risks, the loss of biodiversity on agricultural areas, and the decline in soil fertility. Burning crop residue considerably increases the amount of air pollutants such as CO₂, CO, NH₃, NOₓ, SOₓ, Non-methane hydrocarbon (NMHC), volatile organic compounds (VOCs), and semi volatile organic compounds (SVOCs), as well as particulate matter (PM). This is primarily responsible for the loss of organic carbon, nitrogen, and other nutrients that the soil would have otherwise kept.

**Table 2:** Major pollutants emitted during crop residue burning

<table>
<thead>
<tr>
<th>Category</th>
<th>Pollutants</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulates</td>
<td>SPM (PM₁₀₀)</td>
<td>Incomplete combustion of inorganic material, particle on burnt soil</td>
</tr>
<tr>
<td></td>
<td>RPM (PM₁₀)</td>
<td>Condensation after combustion of gases and incomplete combustion of organic matter</td>
</tr>
<tr>
<td></td>
<td>FPM (PM₂.₅)</td>
<td></td>
</tr>
<tr>
<td>Gases</td>
<td>CO</td>
<td>Incomplete combustion of organic matter</td>
</tr>
<tr>
<td></td>
<td>NO₂</td>
<td>Oxidation of N₂ in air at high temperature</td>
</tr>
<tr>
<td></td>
<td>N₂O</td>
<td></td>
</tr>
<tr>
<td></td>
<td>O₃</td>
<td>Secondary pollutant, form due to Nitrogen Oxide and Hydrocarbon</td>
</tr>
<tr>
<td></td>
<td>CH₄</td>
<td>Incomplete combustion of organic matter</td>
</tr>
</tbody>
</table>

Singh et al. (2021) [11]
wheat treated with rice straw and green manure had considerably greater levels of organic carbon, available nitrogen, available phosphorus, and available potassium compared to other treatments.

Burning crop residue raises the soil temperature to between 33.8 and 42.2°C. Additionally, burning lowers the bacterial and fungal populations in the top 2.5 cm of soil. Even though the effect is transient, as bacteria regrow after a few days, frequent burning in a field may permanently reduce the microbial population. According to Chandra (2018) [1], the incorporation of rice residue at different crop growth periods had a substantial effect on the carbon content of microbial biomass. The highest microbial biomass carbon was recorded under rice stubble along with Trichoderma and Conventional tillage. Augmentation of microbial biomass Carbon may be attributable to a high supply of organic substrate during different stages of growth, but a sudden fall in microbial biomass may be attributable to a low availability of substrate during harvesting.

3. Strategies and technological interventions for Crop residue management

3.1 Incorporation of crop residues

Incorporation of crop residue into soil through adoption of conservation agriculture practices helps to prevent soil erosion from wind & water and to augment the soil moisture. In addition, crop residue incorporation also helps in reducing weed infestation. Khankhane et al. (2009) [6] reported that weed density and weed dry weight in residue incorporation treatment were on par with burning treatment. Dotaniya (2013) [4] reported that crop residue incorporated treatment recorded significantly higher yields of both rice and wheat and also higher nutrient uptakes in both the crops. This might be mainly attributed to microbial decomposition which converts crop residues easily into mineralizable form.

3.2 Composting

Promoting the use of crop residues for the creation of bio-enriched compost or vermicomposting and their usage as farm yard manure is one of the key strategies for reducing crop residue burning. In comparison to all other treatments, Phalke (2015) found that soybean seed yield, soybean protein content, maize grain yield, and maize starch content rose considerably greater levels of organic carbon, available nitrogen, available phosphorus, and available potassium compared to other treatments.

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3.3 Bio char

Bio char is a fine-grained, carbon-rich, porous result of the thermochemical process pyrolysis, which occurs at low temperatures in the absence of oxygen. It consists of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulphur (S), and ash in variable proportions. When added to soil, extremely porous structure of bio char promotes water retention and surface area. It interacts primarily with the soil matrix, soil microbes, and plant roots, aids in nutrient retention, and initiates a vast array of biogeochemical processes. According to Coumaravel et al. (2015) [3] in Coimbatore, maize grain production was greatest with NPK + FYM @12.5 t ha⁻¹ + Bio char @ 15 t ha⁻¹ + Azospirillum @ 2 kg ha⁻¹, demonstrating that
maize responded to biochar application when applied under IPNS. The reaction to biochar was most significant when treated with FYM and Azospirillum, followed by NPK alone. This could be attributed to the increased nutrient availability, which increased grain yield when biochar was sprayed with FYM + Azospirillum or NPK fertilizer.

3.4 Minimum tillage and Zero tillage
The term "minimum tillage" refers to the cultivation of a crop using only the tillage required for planting seeds at the correct depth and then covering them. The objective is to reduce tilling to the bare minimum required to ensure a good seedbed, rapid germination, adequate stands, and favorable growing conditions. Zero tillage refers to no tillage in which the crop is planted on unprepared soil by opening a narrow slot, trench, or band of adequate width and depth to ensure adequate seed coverage.

3.5 Crop diversification and alternate cropping systems
Crop rotation, crop diversification, and alternative farming techniques are crucial for preventing crop residue burning. The rice-yellow sarson-groundnut planting sequence had much greater grain yield and straw yield than the rice-wheat cropping sequence, but was statistically equivalent to the rice-vegetable pea-corn cropping series.

3.6 Mechanical intensification against crop residue burning
Utilization of agricultural machinery and equipment, such as the happy seeder, turbo seeder, rotovator, baling machines, zero-till seed drill, etc., to allow in-situ management of crop residue and retention of straw as surface mulching. Thind et al. (2014) evaluated various establishing strategies and residue management approaches in rice and wheat and found that zero tillage-direct seeded rice was comparable to conventional tillage-direct seeded rice and transplanted rice. Singh et al. (2013) observed in three districts of Patiala, Fatehgarh Sahib, and Kapurthala, Punjab, that grain production, straw yield of wheat, and economic indicators including gross returns, net returns, and BC ratio were significantly greater with happy seeder than with rotovator and farmer practice. It may be attributed to the increased number of tillers per plant and the length of the ear. Second, the presence of paddy straw on the surface of the soil may have increased the availability of moisture throughout the growing season. Due to a larger grain yield, this method of sowing produced greater gross returns than the inclusion technique. Happy seeder had a lower BC ratio than incorporation and the standard way of sowing as a result of its significantly lower cultivation costs.

4. Conclusion
It has been observed from the above research studies that in situ incorporation of crop residues can improve soil physicochemical and microbial properties which resulted in subsequent increase of yields. Biochar due to its stable nature can reduce CO₂ and other gaseous emissions by sequestering into the soil. Crop diversification with residue management through organics can be advocated for increasing rice productivity, improving soil health profitability and conserving energy and Happy seeder technology not only saves time for sowing of next crop, but also results in higher profitability. Thus, it can take part in retaining soil health as well as environmental health.

5. Future line of work
There is a need to study on nutrient management in crop residue incorporation, assess the use of compost culture to enhance the decomposition of crop residues and more research has to be conducted on natural farming technologies like use of crop residue as mulching and use of microbial consortia for enhancing decomposition and converting to humus etc.

6. References


